

## **WASTE OIL ELECTRICAL GENERATION SYSTEM**

### **CROSS-REFERENCE TO RELATED APPLICATION**

The present application is related to prior provisional application Serial Number 60/425,605, filed 11/12/02, entitled "WASTE OIL ELECTRICAL GENERATION SYSTEM", from which priority is claimed, the contents of which are incorporated herein by this reference and are not admitted to be prior art with respect to the present invention by the mention in this cross-reference section.

### **BACKGROUND**

This invention relates to providing an improved electrical generation system utilizing waste oil as a combustible fuel. More particularly, this invention relates to the co-generation of electrical power using a generator powered by the heat energy produced by a waste-oil-fired furnace.

Approximately 1.4 billion gallons of used oil is generated in the United States each year. Approximately ten percent of that amount is properly recycled, with the remainder dumped into the environment. Waste oil dumping has increasingly become a major worldwide environmental issue. It has been shown that one gallon of waste oil can contaminate up to one million gallons of water. Currently, forty percent of the pollution found in the waterways of the United States is created by waste oil, with similar pollution statistics reported by other industrialized countries.

In 1980 the U.S. Congress passed the *Used Oil Recycling Act* to establish a national policy governing used oil. One significant aspect of the legislation was the acceptance of on-site burning of waste oil to produce usable heat. Government leaders recognized that making used oil valuable for hundreds of thousands of small businesses was the best way to prevent dumping and water pollution.

In the United States, the Environmental Protection Agency (EPA) currently acts to establish, monitor and manage waste oil control guidelines in an attempt reduce hazardous environmental waste oil contamination from waste oil dumping. The EPA's rule generally states:

#### ***TITLE 40--PROTECTION OF ENVIRONMENT***

#### ***PART 279--STANDARDS FOR THE MANAGEMENT OF USED OIL--Table of Contents***

#### ***Subpart C--Standards for Used Oil Generators***

*Sec. 279.23 On-site burning in space heaters.*

*Generators may burn used oil in used oil-fired space heaters provided that:*

- (a) The heater burns only used oil that the owner or operator generates or used oil received from household do-it-yourself used oil generators;*
- (b) The heater is designed to have a maximum capacity of not more than 0.5 million Btu per hour; and*
- (c) The combustion gases from the heater are vented to the ambient air.*

*[57 FR 41612, Sept. 10, 1992, as amended at 58 FR 26425, May 3, 1993]*

Efficient burning of waste oil is a relatively complex problem. Typically, the waste oil being burned is a mixture of several oil types, each having unique physical characteristics (such as varying densities and flow viscosities).

There are a number of manufacturers that have developed efficient waste oil burners, currently marketing their products throughout the world. The outputs of the burners are currently limited to hot air for space heating and/or usable hot water. These units are sold to businesses that generate waste (used) oil from their operations. They include businesses, such as automotive repair shops, retail outlets that sell oil to consumers, truck shops, farm equipment, heavy equipment, dealerships, bus fleets, commercial fleets, municipalities, construction and mining companies, recycling and landfill centers, manufacturing facilities, and food production/restaurants. The EPA and CE have approved this type of waste oil burning process without a permit, as long as the EPA's burning criteria are met (as noted above).

Despite the high level of efficiency of current waste oil burners, as much as seventy percent of the combustion heat produced by a unit is lost as exhaust. It is clear that a need exists for an improved waste oil burning system that better utilizes valuable generated heat energy currently lost from existing systems.

#### OBJECTS OF THE INVENTION

It is an object and feature of the present invention to provide an effective, efficient system for the combustion of waste oil.

It is a further object and feature of the present invention to provide such a system that utilizes Stirling-cycle engines.

It is a further object and feature of the present invention to provide such a system that utilizes such Stirling-cycle engines to provide electrical energy.

It is a further object and feature of the present invention to provide such a system that utilizes the combustion energy of the waste oil to provide space heating.

It is a further object and feature of the present invention to provide such a system that utilizes the combustion energy of the waste oil to provide a usable hot water source.

It is a further object and feature of the present invention to provide such a system that is capable of supplying excess generated electrical power to a larger electrical power grid.

It is a further object and feature of the present invention to provide such a system that is capable of storing excess generated electrical power in a battery storage system.

It is a further object and feature of the present invention to provide such a system that is capable of economically disposing of environmentally-hazardous waste oil.

A further primary object and feature of the present invention is to provide such a system that is efficient, inexpensive and handy. Other objects and features of this invention will become apparent with reference to the following descriptions.

#### SUMMARY OF THE INVENTION

An electrical generation system comprising: electrical circuit means for utilizing electrical power; connected to such electrical circuit means, stirling-cycle power means for using the mechanical output of at least one Stirling cycle to produce electrical power; holding means for holding environmentally hazardous waste oils; combustion heat means for producing combustion heat by burning such environmentally hazardous waste oils; waste oil transfer means for transferring such environmentally hazardous waste oils from such holding means to such combustion heat means; and primary heat transfer means for transferring of such combustion heat to such Stirling-cycle means; wherein such primary heat transfer means is in operational communication with such combustion heat means; and wherein such environmentally hazardous waste oils may be converted to electrical power. Moreover, it provides such a system wherein such electrical circuit means comprises electrical network means for linking to at least one larger electrical grid. Additionally, it

provides such a system wherein such electrical network means further comprises electrical controller means for controlling electrical power within such electrical network means.

Also, it provides such a system wherein such electrical controller means is structured and arranged to control electrical power flowing between such electrical network means and the at least one larger electrical grid. In addition, it provides such a system wherein: such electrical network means further comprises electrical storing means for storing electrical power; and such electrical controller means is structured and arranged to control at least one transfer of electrical power between such electrical storing means and such electrical network means. And, it provides such a system further comprising secondary heat transfer means for transferring at least one portion of the combustion heat to at least one heatable fluid. Further, it provides such a system wherein such secondary heat transfer means is structured and arranged to transfer heat to air, usable for space heating. Even further, it provides such a system wherein the heatable fluid comprises at least one liquid. Moreover, it provides such a system wherein such holding means comprises collector means for collecting of such environmentally hazardous waste oils. Additionally, it provides such a system wherein such combustion heat means comprises: atomizer means for atomizing such environmentally hazardous waste oils prior to combustion; and igniter means for igniting such environmentally hazardous waste oils after such environmentally hazardous waste oils have passed through such atomizing means.

Also, it provides such a system wherein such waste oil transfer means comprises: pump means for pumping such environmentally hazardous waste oils from such holding means to such combustion heat means; flow volume regulator means for regulating the flow volume of such environmentally hazardous waste oils pumped from such holding means to such combustion heat means; and pre-heater means for preheating such environmentally hazardous waste oils prior to burning.

In accordance with another preferred embodiment hereof, this invention provides an electrical generation system comprising: at least one electrical circuit structured and arranged to utilize electrical power; connected to such at least one electrical circuit, at least one Stirling-cycle engine structured and arranged to use the mechanical output of at least one Stirling cycle to produce electrical power; at least one holder structured and arranged to hold environmentally hazardous waste oils; at least one combustion heater structured and

arranged to produce combustion heat by burning such environmentally hazardous waste oils; at least one waste oil transfer component structured and arranged to transfer such environmentally hazardous waste oils from such at least one holder to such at least one combustion heater; and at least one primary heat exchanger structured and arranged to transfer such combustion heat to such at least one Stirling-cycle engine; wherein such at least one primary heat exchanger is in operational communication with such at least one combustion heater; and wherein such environmentally hazardous waste oils may be converted to electrical power. In addition, it provides such a system wherein such at least one electrical circuit comprises at least one electrical network to at least one larger electrical grid. And, it provides such a system wherein such at least one electrical network further comprises at least one electrical controller structured and arranged to control electrical power within such at least one electrical network. Further, it provides such a system wherein such at least one electrical controller is structured and arranged to control electrical power flowing between such at least one electrical network and the at least one larger electrical grid.

Even further, it provides such a system wherein: such at least one electrical network further comprises at least one electrical storage device structured and arranged to store electrical power; and such at least one electrical controller is structured and arranged to control at least one transfer of electrical power between such at least one electrical storage device and such at least electrical network. Moreover, it provides such a system further comprising at least one secondary heat exchanger structured and arranged to transfer at least one portion of the combustion heat to at least one heatable fluid. Additionally, it provides such a system wherein such at least one secondary heat exchanger is structured and arranged to transfer heat to air, usable for space heating. Also, it provides such a system wherein the heatable fluid comprises at least one liquid. In addition, it provides such a system wherein such at least one holder comprises at least one collector structured and arranged to assist in collecting such environmentally hazardous waste oils. And, it provides such a system wherein such at least one combustion heater comprises: at least one atomizer structured and arranged to atomize such environmentally hazardous waste oils prior to combustion; and at least one igniter adapted to ignite such environmentally hazardous waste oils after such environmentally hazardous waste oils have passed through such at least one atomizer.

Further, it provides such a system wherein: such combustion heat produced by such at least one combustion heater comprises at least one directed heat flow; at least one portion of such at least one primary heat exchanger is positioned to be in thermal communication with such at least one directed heat flow; and such at least one primary heat exchanger is structured and arranged to direct at least one portion of such at least one directed heat flow to such at least one secondary heat exchanger. Even further, it provides such a system wherein such at least one waste oil transfer component comprises: at least one pump to pump such environmentally hazardous waste oils from such at least one holder to such at least one combustion heater; at least one flow volume regulator adapted to regulate the flow volume of such environmentally hazardous waste oils pumped from such at least one holder to such at least one combustion heater; and at least one pre-heater structured and arranged to preheat such environmentally hazardous waste oils prior to burning. Even further, it provides such a system further comprising: at least one power producing site having at least one such electrical circuit, and at least one operation to generate such environmentally hazardous waste oils; wherein the at least one operation is performed within the power producing site; wherein at least one such electrical circuit generates electrical power and at least one useful form of usable energy selected from the group consisting of: heated air, heated liquid, wherein such at least one combustion heater has a maximum capacity of not more than 0.5 million BTU input per hour; and wherein combustion gasses produced by the combustion of such environmentally hazardous waste oils is vented to the outside air. Even further, it provides such a system wherein the at least one operation comprises collection of the waste oil from at least one non-commercial source.

In accordance with another preferred embodiment hereof, this invention provides a method for economically disposing of waste oil comprising the steps of: collecting environmentally hazardous waste oils; combusting such environmentally hazardous waste oils to produce usable heat energy; and using such usable heat energy to power at least one Stirling-cycle engine; using the output from such Stirling-cycle engine to generate useful electrical power. Even further, it provides such a method further comprising using surplus usable heat energy from combusting such environmentally hazardous waste oils for on-site heating uses. Even further, it provides such a method further comprising the initial step of collecting such environmentally hazardous waste oils from at least one off-site, non-

commercial, waste oil source. Even further, it provides such a method further comprising the step of selling at least one portion of such useful electrical power using at least one electrical grid connection.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic sectional view, illustrating in general, the operational principles of a typical Stirling-cycle system.

FIG. 2 is a diagrammatic perspective view, illustrating in general, a typical organization of waste oil distributed cogeneration sites linked to a larger electrical power grid, as well as remote waste oil electrical generation sites independent from a larger power distribution system, according to a preferred embodiment of the present invention.

FIG. 3 is a diagrammatic illustration of the principal components of the waste oil cogeneration system according to the preferred embodiment of FIG. 2.

FIG. 4 is a diagrammatic illustration of the secondary fluid heat exchanger according to the preferred embodiment of FIG. 3.

FIG. 5 is a diagrammatic illustration of the secondary fluid heat exchanger showing the working fluid heat exchanger introduced into the combustion chamber according to the preferred embodiment of FIG. 3.

FIG. 6 is a diagrammatic configuration view of a waste oil cogeneration system according to a preferred embodiment of the present invention.

FIG. 7 is a perspective view, in partial section, of the waste oil cogeneration system of the preferred embodiment of FIG. 6.

FIG. 8 is a diagrammatic sectional view of an alternate preferred waste oil cogeneration system according to an alternate preferred embodiment of the present invention.

FIG. 8a is a diagrammatic illustration, partially in section, of the torodial-shaped working fluid heat exchanger, Stirling-cycle engine, and electrical generator of the alternate preferred embodiment of FIG. 8.

FIG. 9 is a diagrammatic sectional view of a waste oil cogeneration system according to yet another preferred embodiment of the present invention.

FIG. 10 is a sectional view through a typical waste oil combustor according to a preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Stirling-cycle engines were originally patented in 1816 and were commonly used prior to World War I. Stirling-cycle technology quickly became a popular alternative to steam engines due, in part, to a better operational safety record (early Stirling engines commonly used air as the working fluid). As steam engine technology improved, the Stirling engine eventually lost favor. Recent interest in distributed energy generation has revived interest in Stirling engines and, as a result, research and development efforts have increased.

The theoretical and practical design of the Stirling-cycle engine is known in the art, and therefore, will not be discussed at length within this disclosure. It is noted that the design and operation of such Stirling-cycle devices is described in greater detail in, for example, the dissertation entitled, "*Stirling Cycle Engine Analysis*", by Dr. Israel Urieli of Ohio University (1884), incorporated herein by reference as prior art enabling, in conjunction with this specification, the below described Stirling-cycle engines.

Stirling engines are classed as external combustion engines, comprising a sealed system utilizing an inert internal working fluid (typically a gas, such as helium), in conjunction with an external heat source and heat exchanger. Stirling-cycle engines take advantage of the relationship between heat, volume and pressure of a gas to produce mechanical power.

Referring now to FIG. 1, in typical Stirling-cycle engine 40, heat 50 is transferred to working gas 52 through heat exchanger 54. Pressure of working gas 52 rises with the increased gas temperature as working gas 52 is held within the fixed volume of sealed cylinder 56. This increase in the pressure of working gas 52 pushes piston 58 to perform mechanical work. As piston 58 reaches a position of maximum cylinder volume 60, mechanical displacement mechanism 61 moves working gas 52 from the above-described "hot" portion of the engine 66 through "regenerator" 62 to a "cool" portion of the engine 64. In moving through regenerator 62, heat from working gas 52 is temporarily stored. Mechanical displacement mechanism 61 continues to move the cooled working gas 52 through the cycle in such a way as to move and compress cooled working gas 52 back to hot portion of the engine 66 through regenerator 62 (where it picks up the heat left behind



within the regenerator matrix). Working gas 52 is further heated in heat exchanger 54 and the cycle begins again. Currently, no Stirling-cycle engine operates on the combustion heat produced by the burning of waste oil.

It is clear from the above discussions that an effective, efficient combination of a Stirling-cycle engine and waste oil burner would be of great economic and environmental benefit. With such combination, a significant portion of the "waste heat" lost in existing waste oil burner designs can be effectively recovered by a Stirling-cycle engine, thereby greatly increasing the overall energy efficiency of the combined system.

It has been determined that waste oil possesses nearly twice the energy value of coal, and more energy than #2 fuel oil. It should be noted that the term "environmentally hazardous waste oils", as used within this specification and the below claims, shall include within the definition those oils classified by the governing agencies as "recyclable" for energy recovery through burning. The applicant has estimated that using such combined used-oil-fired Stirling-cycle engine, one gallon of used oil can generate up to 18-kilowatt hours of electricity.

Operators of an on-site waste-oil-fired electrical generation system may find further economic benefits by selling surplus power back to an electrical utility, via an avoided rate, or net metering program. Additionally, off-grid operators of an on-site waste-oil-fired electrical generation system will benefit from a convenient, packaged source of electrical power, space heat and hot water.

Thus it is therefore a further object and feature of the present invention to provide such a system that converts the combustion energy of waste oil into mechanical energy by use of a Stirling-cycle engine. Thus, it is an additional object and feature of the present invention to provide such a system that utilizes the mechanical output of the Stirling-cycle engine to drive an electrical generator.

Referring again to the drawings, FIG. 2 is a diagrammatic perspective view, illustrating in general, a typical organization of waste oil distributed cogeneration site(s) 102 linked to a larger electrical power grid 120, as well as remote waste oil electrical cogeneration site(s) 126, independent from a larger power distribution system, according to a preferred embodiment of the present invention.

The enlarged cut-away view of distributed cogeneration site 102 (in the upper

portion of FIG. 2) illustrates, in general, the preferred operational and mechanical assemblies that make up a waste oil distributed cogeneration site. Preferably, a significant portion of the on-site electrical power **110** used within the local electrical network of distributed cogeneration site **102** (embodying herein electrical network means for utilizing electrical power and embodying herein at least one electrical network structured and arranged to utilize electrical power) is produced by on-site waste oil cogeneration system **100** (embodying herein Stirling-cycle power means for using the mechanical output of at least one Stirling-cycle to produce electrical power), as shown. Waste oil cogeneration system **100** is especially well- suited for use within sites that regularly generate waste oil, such as motor vehicle service shops, fleet maintenance facilities, “quick-lube” shops, and other operations that service, repair or dispose of materials that contain quantities of synthetic or refined crude oil (embodying herein a power- producing site having at least one such electrical generation system, and at least one operation to generate such environmentally hazardous waste oils; wherein the at least one operation is performed within the power producing site). Under appropriate circumstances, a distributed cogeneration site may collect waste from external, non-commercial sources, such as individuals undertaking “do-it-yourself” vehicle maintenance (embodying herein the initial step of collecting such environmentally hazardous waste oils from at least one off-site, non-commercial, waste oil source). For the purpose of illustration within the present disclosure, distributed cogeneration site **102** of FIG. 2 produces waste oil through the service and maintenance of motor vehicles **106**, as shown. Waste oil **104** collected from the service and maintenance of motor vehicle **106** is preferably transferred to a waste oil collection tank **108** (embodying herein holding means for holding environmentally hazardous waste oils and further embodying herein at least one holder structured and arranged to hold environmentally hazardous waste oils), preferably incorporated within waste oil cogeneration system **100**, as shown. Preferably, waste oil **104** is burned, in controlled manner, within waste oil cogeneration system **100** to produce usable heat energy.

Preferably, the term “cogeneration” refers to the simultaneous production of usable heat and on-site electrical power **110**. In a preferred embodiment of the present invention, waste oil cogeneration system **100** is configured as a multi-generation unit, producing electrical power, hot air **116** (for space-heating) and hot water **114** (embodying herein

wherein the heatable fluid comprises at least one liquid, and embodying herein wherein at least one such electrical generation system generates electrical power and at least one useful form of usable energy selected from the group consisting of heated air, heated liquid), as shown.

Distributed cogeneration site **102** may preferably include an energy storage system **112** to permit added flexibility in the timing and frequency of external electrical power purchases and increased reliability to the overall electrical supply features of the system. To control initial implementation and long-term maintenance costs, energy storage system **112** preferably comprises a conventional battery storage system, as shown (embodying herein wherein such electrical network means further comprises electrical storing means for storing electrical power and further herein embodying wherein such at least one electrical network further comprises at least one electrical storage device structured and arranged to store electrical power). Upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, such as commercial availability, user preference, advances in technology, etc., other storage systems, such as, for example, super capacitors, Superconducting Magnetic Energy Storage (SMES) systems, flywheels and Compressed Air Energy Storage (CAES) systems, may suffice.

Preferably, distributed cogeneration site(s) **102** located near or within an external electrical power distribution system, such as larger electrical power grid **120**, include at least one electrical grid connection **118** (herein embodying wherein such electrical network means comprises at least one electrical link to at least one larger electrical grid, and embodying herein wherein such at least one electrical network comprises at least one electrical link to at least one larger electrical grid), as shown. Preferably, distributed cogeneration site **102** supplies any excess electrical power generated by waste oil cogeneration system **100** to larger electrical power grid **120**, via electrical grid connection **118**, as shown. Similarly, electrical grid connection **118** allows distributed cogeneration site **102** to draw electrical power from central generating plant **122**, via larger electrical power grid **120**, in circumstances where the overall power demand of distributed cogeneration site **102** exceeds the generation capacity of waste oil cogeneration system **100**. The term “distributed cogeneration”, as described within the present disclosure, refers to a decentralization of electrical power generation from traditional large “utility” scale

generation sites (such as central generating plant **122**) to a combination of conventional large scale generation sites functioning in conjunction with a “near-demand” distribution of smaller, “on-site” electrical generators, as shown. While central generating plant **122** continues to provide most of the power to larger electrical power grid **120**, the distributed cogeneration site(s) **102** are, under appropriate circumstances, able to supply power to other local power users during times of peak demand, as shown.

In another highly-preferred application of the present invention, waste oil cogeneration system **100** is used to supply electrical power and usable heat energy to remote waste oil electrical cogeneration site **126**, as shown. Waste oil electrical cogeneration site **126** is located such that connection to larger electrical power grid **120** is impossible or otherwise impractical. In the case of remote waste oil electrical cogeneration site **126**, waste oil cogeneration system **100** preferably supplies all electrical power and at least some mechanical heating to the site.

FIG. 3 is a diagrammatic illustration of the principal components of waste oil cogeneration system **100**, according to the preferred embodiment of FIG. 2. Preferably, waste oil cogeneration system **100** contains at least one waste oil combustor **130** (embodying herein combustion heat means for producing combustion heat by burning such environmentally hazardous waste oils and embodying herein at least one combustion heater structured and arranged to produce combustion heat by burning such environmentally hazardous waste oils) that combines oil **104** with compressed air **128** to form a highly combustible air/fuel mixture. Igniting the mixture of waste oil **104** and compressed air **128** generates combustion heat energy **132**, as shown.

A primary function of waste oil electrical cogeneration system **100** is the conversion of combustion heat energy **132** into electrical power **140**, as shown. The conversion of combustion heat energy **132** into electrical power is accomplished through a basic multi-step process. Preferably, working fluid heat exchanger **136** (embodying primary heat transfer means for transferring of such combustion heat to such Stirling-cycle means) is brought into thermal relationship with combustion heat energy **132** (herein embodying wherein such primary heat transfer means is in operational communication with such combustion heat means, and further embodying herein at least one primary heat exchanger structured and arranged to transfer such combustion heat to such at least one Stirling-cycle engine),

initiating the transfer of heat from combustion heat energy **132** to Stirling-cycle engine **134**, as shown. Preferably, Stirling-cycle engine **134** is arranged to convert the heat transferred by working fluid heat exchanger **136** into mechanical energy **133** (e.g., torque within a rotating output shaft), as shown. Preferably, Stirling-cycle engine **134** is operationally coupled to electrical generator **138**, which then converts mechanical energy **133** into electrical power **140** (embodying herein at least one Stirling-cycle engine structured and arranged to use the mechanical output of at least one Stirling cycle to produce electrical power).

As previously described, waste oil electrical cogeneration system **100** is preferably a cogeneration (or multi-generation) unit wherein secondary energy, in the form of usable heat, is derived from the system. In the example of FIG. 3, secondary fluid heat exchanger **144** (embodying herein secondary heat transfer means for transferring at least one portion of the combustion heat to at least one heatable fluid, and further embodying herein at least one secondary heat exchanger structured and arranged to transfer at least one portion of the combustion heat to at least one heatable fluid) is brought into thermal relationship with combustion heat energy **132**, drawing usable heat from combustion heat energy **132**, as shown.

FIG. 4 is a diagrammatic illustration of secondary fluid heat exchanger **144**, according to the preferred embodiment of FIG. 3. In the highly simplified model of FIG. 4, secondary fluid heat exchanger **144** comprises two approximately concentric pipes, each pipe having an input and output. Preferably, incoming combustion heat **146** is introduced into and moves through combustion chamber **147** before exiting as outgoing combustion heat **148**, as shown. Similarly, a lower temperature incoming secondary fluid **150** is introduced into secondary fluid channel **151**, where it moves around combustion chamber **147** before exiting as outgoing secondary fluid **152**, as shown. As incoming secondary fluid passes around combustion chamber **147**, heat energy is transferred from incoming combustion heat **146** to the lower temperature incoming secondary fluid **150**, across secondary heat exchanger wall **149**, thereby raising the temperature of incoming secondary fluid **150**. In practical application, the efficiency of heat-energy transfer across secondary heat exchanger wall **149** can never achieve one-hundred percent. Due to factors such as transfer surface area and material heat-transfer rates, a significant percentage of the heat

energy of incoming combustion heat **146** will remain in outgoing combustion heat **148**, discharged from the system as waste exhaust. Oil combustion burner systems for space heating may discharge as much as seventy percent of outgoing combustion heat **148** as waste exhaust.

FIG. 5 is a diagrammatic illustration of secondary fluid heat exchanger **144**, showing working fluid heat exchanger **136** introduced into combustion chamber **147**, according to the preferred embodiment of FIG. 3. By placing working fluid heat exchanger **136** into combustion chamber **147**, waste oil electrical cogeneration system **100** effectively captures and utilizes heat energy of outgoing combustion heat **148** that is normally lost as waste exhaust, as shown. It should be noted that the introduction of working fluid heat exchanger **136** into combustion chamber **147** has no significant impact on the quantity or rate of heat energy transfer from incoming combustion heat **146** to incoming secondary fluid **150** across secondary heat exchanger wall **149**.

FIG. 6 is a diagrammatic sectional view of waste oil cogeneration system **100**, according to a preferred embodiment of the present invention. Preferably, waste oil electrical cogeneration system **100** is an assembly comprised of waste-oil-fired hot air furnace **153**, modified to receive Stirling-cycle engine **134** and electrical generator **138**, as shown. Preferably, waste-oil-fired hot air furnace **153** is a commercially available unit, for example, waste-oil-fired hot air furnaces produced by Clean Burn, Inc. of Leola, Pennsylvania, U.S.A. Waste oil burning devices of this type are also known by those skilled in the art as “multi-oil furnaces”, and typically include a number of specific features to allow for efficient combustion of multiple waste oil types having varying physical properties.

In a typical arrangement, waste oil **104** is preferably held in waste oil collection tank **108** of waste oil electrical cogeneration system **100** prior to being transferred to waste oil combustor **130**, via waste oil transfer assembly **158** (embodying herein waste oil transfer means for transferring such environmentally hazardous waste oils from such holding means to such combustion heat means and herein embodying at least one waste oil transfer component structured and arranged to transfer such environmentally hazardous waste oils from such at least one holder to such at least one combustion heater), as shown. Preferably, waste oil transfer assembly **158** includes waste oil pump **160** (embodying herein pump

means for pumping such environmentally hazardous waste oils from such holding means to such combustion heat means, and further embodying herein at least one pump structured and arranged to pump such environmentally hazardous waste oils from such at least one holder to such at least one combustion heater), as shown. Typically, waste oil **104** is pre-conditioned before reaching waste oil combustor **130** by passing through waste oil volume/viscosity control **162**, as shown. Pre-conditioning provided by waste oil volume/viscosity control **162** typically includes such actions as flow rate sampling, control of waste oil transfer rate and pre-heating of waste oil **104** to assist in managing oil viscosity for optimal combustion conditions within combustion chamber **147**, as shown (embodying herein flow volume regulator means for regulating the flow volume of such environmentally hazardous waste oils pumped from such holding means to such combustion heat means; and pre-heater means for preheating such environmentally hazardous waste oils prior to burning, and further embodying herein at least one flow volume regulator structured and arranged to regulate the flow volume of such environmentally hazardous waste oils pumped from such at least one holder to such at least one combustion heater; and at least one pre-heater structured and arranged to preheat such environmentally hazardous waste oils prior to burning). It is noted that the configuration and operation of such waste oil pre-conditioning devices is described in greater detail in, for example, U.S. Patent No. 5,551,868 to Smoker et al., incorporated herein by reference for further examples of implementation engineering. Preferably, waste oil combustor **130** is a highly efficient design, comprising at least one burner nozzle that combines a flow of compressed air **128** with a flow of pre-heated waste oil **104** (embodying herein atomizer means for atomizing such environmentally hazardous waste oils prior to combustion, and embodying herein at least one atomizer structured and arranged to atomize such environmentally hazardous waste oils prior to combustion). Preferably, the mixture of compressed air **128** and waste oil **104** is injected into combustion chamber **147**, where ignition assembly **117** (embodying herein igniter means for igniting such environmentally hazardous waste oils after such environmentally hazardous waste oils have passed through such atomizing means, and further embodying herein at least one igniter structured and arranged to ignite such environmentally hazardous waste oils after such environmentally hazardous waste oils have passed through such at least one atomizer) ignites the atomized mixture generating a focused combustion flame **156** directed to the

interior of combustion chamber **147** (see also FIG. 10) . It is noted that the configuration and operation of waste oil combustors (such as waste oil combustor **130**) is described in greater detail in, for example, U.S. Patent No. 6,048,197 to Beiler, incorporated herein by reference for further examples of implementation engineering. Commercially-available waste oil combustors of the type preferably used in the present invention may be supplied with an approximate thermal output ranging from about 100,000 BTUs/hr to over 500,000 BTUs/hr at temperatures of up to about 2,000 degrees Fahrenheit (embodying herein wherein such at least one combustion heater has a maximum capacity of not more than 0.5 million BTU input per hour).

Preferably, secondary fluid heat exchanger **144** of waste-oil-fired hot air furnace **153** comprises at least one combustion chamber **147** surrounded on all sides by heat exchanger air channel **166**, as shown. Preferably, air intake fan **164** moves the secondary fluid (comprising air in the present embodiment) through heat exchanger air channel **166**, where it is heated before passing out of heat exchanger air channel **166** by means of hot air discharge **168**, as shown. The heated air exiting hot air discharge **168** is preferably used to provide local space heating (embodying herein wherein such secondary heat transfer means is structured and arranged to transfer heat to air usable for space heating, and further embodying herein wherein such at least one secondary heat exchanger is structured and arranged to transfer heat to air usable for space heating) within the waste oil electrical cogeneration system site (as previously described in FIG. 2). Preferably, combustion chamber **147** includes combustion gas discharge flue **170** to remove spent combustion gases from the system, as shown (embodying herein wherein combustion gasses produced by the combustion of such environmentally hazardous waste oils is vented to the outside air). It is noted that the configuration and operation of such a secondary fluid heat exchanger is described in greater detail in, for example, U.S. Patent No. 5,531,212 to Smoker et al., incorporated herein by reference for further examples of implementation engineering.

Applicant prefers that, in applicant's waste-oil-fired hot air furnace **153**, working fluid heat exchanger **136** is introduced into combustion chamber **147** through back wall **157** (as apposed to Smoker et al., for example), thereby permitting a portion of the heat energy from the directed combustion flame **156** (herein embodying at least one directed heat flow) to be transferred to Stirling-cycle engine **134**, as shown. Preferably, the configuration of



working fluid heat exchanger **136** is such that combustion flame **156** is directed back in combustion chamber **147**, thereby maintaining the overall efficiency of the combustion and secondary heat transfer process, as shown (herein embodying wherein such combustion heat produced by such at least one combustion heater comprises at least one directed heat flow; at least one portion of such at least one primary heat exchanger is positioned to be in thermal communication with such at least one directed heat flow; and such at least one primary heat exchanger is structured and arranged to direct at least one portion of such at least one directed heat flow to such at least one secondary heat exchanger). Upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, such as, to accommodate specific furnace thermal performance characteristics, user preference, advances in technology, etc., other positions of the working fluid heat exchanger within the combustion chamber, such as, for example, non-concentric, front mounted, etc., may suffice.

Preferably, Stirling-cycle engine **134** comprises a 480 cc four-piston alpha configuration, such as Model STM 4-120 produced by Stirling Thermal Motors, Inc. of Ann Arbor, MI, U.S.A. Using a waste oil burner having a combustion flame temperature of approximately 1,400 degrees Fahrenheit (as measured at working fluid heat exchanger **136**), Stirling-cycle engine **134** typically produces about 40 hp at an average shaft speed of about 1800 rpm. Preferably, Stirling-cycle engine **134** is coupled to an “off-the-shelf” induction-type electrical generator **138**, preferably having a rated electrical output (after inverter processing) of 25kW at 480 VAC/3-phase at 60 Hz. Further, Stirling-cycle engine **134** typically produces up to 150,000 BTUs/Hr of hot water from the engine’s internal coolant circuit, delivered by means of Stirling engine coolant lines **172**, as shown.

FIG. 7 is a perspective view, in partial section, of the waste oil cogeneration system **100**, according to the preferred embodiment of FIG. 6. The cut-away view of FIG. 7 more clearly shows the preferred arrangement of working fluid heat exchanger **136** within combustion chamber **147**. Modifications to Stirling-cycle engine **134** required to permit the engine to be incorporated into waste oil cogeneration system **100** are clearly within the abilities of those skilled in the art in light of the present teachings, preferably limited to removal of the factory burner assembly. Preferably, back wall **157** of combustion chamber **147** is prepared to receive Stirling-cycle engine **134**, by cutting heat exchange aperture **171**

through back wall **157**, and by further locating and drilling appropriately-sized mounting holes matching the standard mounting holes of the Stirling-cycle engine factory burner assembly. Upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, such as heavy duty applications, specific furnace/engine combinations, etc., other assemblies, such as, for example, additional plate adapters and/or reinforcing added to back wall **157** to further anchor and support Stirling-cycle engine **134**, may suffice. Preferably, working fluid transfer lines **194** of working fluid heat exchanger **136** are oriented to be in direct contact with the focus of combustion flame **156**, as shown. Upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, such as to enhance the performance of the heat transfer processes within the waste oil cogeneration system, the use of other heat-retaining, heat-blocking and heat-directing elements, such as, for example, ceramic shapes, heat-resistant deflectors, etc., may be used at various positions within the combustion chamber. For example, a metallic or ceramic heat-directing ring placed around working fluid heat exchanger **136** to control the return path of combustion flame **156**, may suffice.

Preferably, the overall configuration of waste oil cogeneration system **100** comprises a self-contained unit having an internal system support structure **176**, preferably constructed from metal, preferably steel, as shown. Preferably, all external access panels **192** are removable for servicing and inspection, as shown. Preferably, collection tank **108** includes one or more waste oil collection assemblies **190** to assist in the collection and storage of waste oil **104**, as shown (embodying herein wherein such holding means comprises collector means for collecting of such environmentally hazardous waste oils and further embodying herein wherein such at least one holder comprises at least one collector structured and arranged to assist in collecting such environmentally hazardous waste oils). Upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, such as to address issues of user preference, advances in technology, etc., other locations for the waste oil collection point, such as, for example, exterior collection assemblies, remote collection areas, etc., may suffice.

Electrical power assemblies **178** preferably route power from electrical generator **138** to electrical power controls **180** mounted on or near waste oil cogeneration system **100**, as shown. Preferably, electrical power controls **180** include such devices as: safety breakers,

power disconnects, power monitors and controllers, charge controllers for a battery storage system (embodying herein wherein such electrical controller means is structured and arranged to control at least one transfer of electrical power between such electrical storing means and such electrical network means) and power inverters, including trace PS and SW series inverters for utility grid connection capability (embodying herein wherein such electrical network means further comprises electrical controller means for controlling electrical power within such electrical network means and wherein such electrical controller means is structured and arranged to control electrical power flowing between such electrical network means and the at least one larger electrical grid and further embodying herein wherein such at least one electrical network further comprises at least one electrical controller structured and arranged to control electrical power within such at least one electrical network, and wherein such at least one electrical controller is structured and arranged to control electrical power flowing between such at least one electrical network and the at least one larger electrical grid), thereby permitting the sale of surplus-generated power back to the utility through net metering or similar programs (embodying herein using surplus usable heat energy from combusting such environmentally hazardous waste oils for on-site heating uses). Further, those of ordinary skill in the art will, upon reading this specification understand that, under appropriate circumstances, electrical power controls **180** may include internal power metering to allow, for example, the manufacturer of waste oil cogeneration system **100** to place units within a waste oil cogeneration site on a cost partnership basis (where all or a pre-arranged portion of the electrical power generated by waste oil cogeneration system **100** is sold by the manufacturer to the co-generating site, at a grid competitive or pre-arranged rate). The above-described preferred arrangement herein embodies: collecting environmentally hazardous waste oils; combusting such environmentally hazardous waste oils to produce usable heat energy; using such usable heat energy to power at least one Stirling-cycle engine; using the output from such Stirling-cycle engine to generate useful electrical power; and selling at least one portion of such useful electrical power by way of at least one electrical grid connection.

Preferably, waste oil cogeneration system **100** is scalable to larger generation applications by using the combined generating power of multiple waste oil cogeneration system(s) **100**.

FIG. 8 is a diagrammatic sectional view of an alternate preferred waste oil cogeneration system **100**, according to another highly preferred embodiment of the present invention. Preferably, waste oil electrical cogeneration system **100** is an assembly comprised of waste-oil-fired hot air furnace **153** modified to receive toroidal-shaped heat exchanger **196** of Stirling-cycle engine **135**, as shown. Preferably, waste-oil-fired hot air furnace **153** is a commercially available unit produced by Black Gold Corporation of Nashville, Tenn., U.S.A.

Preferably, waste oil **104** is held in waste oil collection tank **108** (of waste oil cogeneration system **100**) prior to being transferred to waste oil combustor **130**, via waste oil transfer assembly **158**, as shown. Preferably waste oil transfer assembly **158** includes waste oil pump **160** (embodying herein pump means for pumping such environmentally hazardous waste oils from such holding means to such combustion heat means), as shown. Depending on such factors as temperature and the type of waste oil being burned, waste oil **104** may be pre-conditioned before reaching waste oil combustor **130** by passing through waste oil volume/viscosity control **162**, as shown. Pre-conditioning provided by waste oil volume/viscosity control **162** may include such actions as flow rate sampling, control of waste oil transfer rate and pre-heating of waste oil **104** to assist in managing oil viscosity for optimal combustion conditions within combustion chamber **147**, as shown. Preferably, waste oil combustor **130** comprises a burner nozzle that combines a flow of compressed air **128** with a flow of pre-heated waste oil **104**. Preferably, the mixture of compressed air **128** and waste oil **104** is injected into combustion chamber **147**, where an ignition assembly **117** ignites the atomized mixture generating combustion flame **156**, as shown. It is noted that the configuration and operation of such waste oil pre-conditioning devices is described in greater detail in, for example, U.S. Patent No. 5,879,149 to Briggs et al., incorporated herein by reference for further examples of implementation engineering.

Preferably, secondary fluid heat exchanger **144** of waste-oil-fired hot air furnace **153** comprises combustion chamber **147**, surrounded on all sides by heat exchanger air channel **166**, as shown. Preferably, air intake fan **164** moves the secondary fluid (in this case air) through heat exchanger air channel **166**, where it is heated, before passing out of heat exchanger air channel **166** through hot air discharge **168**, as shown. The heated air exiting hot air discharge **168** is again preferably used to provide local space heating within the

waste oil electrical cogeneration system site (as previously described in FIG. 2). Preferably, combustion chamber **147** includes combustion gas discharge flue **170** to remove spent combustion gases from the system, as shown. It is noted that the configuration and operation of such a secondary fluid heat exchanger is described in greater detail in, for example, U.S. Patent No. 4,955,359 to Briggs et al. and U.S. Patent No. 5,363,836 to Briggs, incorporated herein by reference for further examples of implementation engineering.

Toroidal-shaped heat exchanger **196** is preferably coaxially positioned within the interior of combustion chamber **147**, preferably along the chamber's longitudinal axis, preferably at a position equidistant from waste oil combustor **130** and combustion gas discharge flue **170**, as shown. Toroidal-shaped heat exchanger **196** may be firmly positioned within combustion chamber **147** by a plurality of support members **204** anchored to secondary heat exchanger wall **149**, as shown. Preferably, combustion flame **156** is directed to pass through the interior of toroidal-shaped heat exchanger **196**, as shown. In the preferred embodiment of FIG. 8, working fluid transfer lines **194** provide the fluid transfer path between toroidal-shaped heat exchanger **196**, and Stirling-cycle engine **135**, as shown. The above-described embodiment allows Stirling-cycle engine **135** to be located outside waste-oil-fired hot air furnace **153** in a preferred arrangement, as shown. Upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, such as, user preference, advances in technology, particular space/cost/use circumstances, etc., other selection of internal/external arrangements, may suffice.

As one preferred example, Stirling-cycle engine **135** comprises a 160 cc 90° V-2-cylinder unit, preferably Model V-160 produced by Solo Kleinmotoren GmbH of Sindelfingen, Germany. Using a waste oil burner having a combustion flame temperature of approximately 1,300 degrees Fahrenheit (700° C) (as measured at working fluid heat exchanger **136**), Stirling-cycle engine **135** produces about 11 kW of mechanical power at an average shaft speed of about 1500 rpm (with working fluid heat exchanger **136** maintaining an average working gas pressure of 15 Mpa). Preferably, Stirling-cycle engine **135** is coupled to an induction-type electrical generator **138**, having a rated electrical output (after inverter processing) of 25kW at 480 VAC/3-phase at 60 Hz. Further, Stirling-cycle engine **135** produces up to 150,000 BTUs/Hr of hot water from the engine's internal coolant circuit

delivered through Stirling engine coolant lines **172**, as shown.

FIG. 8a is a diagrammatic illustration, partially in section, of the torodial-shaped working fluid heat exchanger **196**, Stirling-cycle engine **135**, and electrical generator **138** of the alternate preferred embodiment of FIG. 8.

Preferably, toroidal-shaped working fluid heat exchanger **196** is formed from a tightly-coiled arrangement of heat exchange tubes **182**, as shown. Preferably, heat exchange tubes **182** and working fluid transfer lines **194** each comprise 1/4" diameter tubing, preferably constructed from stainless steel or heat-resistant inconel 713/625. Upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, in consideration of such issues as material cost, user preference, advances in technology, etc., other working fluid transfer line configurations, such as, for example, alternate tubing diameters, heat-resistant materials, etc., may suffice.

FIG. 9 is a diagrammatic sectional view of waste oil cogeneration system **100**, according to another preferred embodiment of the present invention. Preferably, waste oil electrical cogeneration system **100** comprises a waste-oil-fired hot water boiler **155** modified to receive Stirling-cycle engine **134**, as shown. As one preferred example, waste-oil-fired hot water boiler **155** may comprise a commercially-available unit produced by Clean Burn, Inc. of Leola, Pennsylvania, U.S.A.

In operation, waste oil **104** is preferably transferred to waste oil combustor **130**, via waste oil transfer line **158**, as shown. As in the prior embodiments of FIG. 6 and FIG. 8, waste oil combustor **130** is preferably a high-efficiency design comprising at least one burner nozzle that combines a flow of compressed air **128** with a flow of pre-heated waste oil **104** that, when ignited within combustion chamber **147**, generates focused combustion flame **156**, as shown. It is noted that the configuration and operation of waste oil combustors, such as waste oil combustor **130**, is described in greater detail in, for example, U.S. Patent No. 6,048,197 to Beiler, incorporated herein by reference for further examples of implementation engineering (see FIG. 10). Commercially-available waste oil combustors of the type preferably used in the present invention may be supplied with an approximate thermal output ranging from about 100,000 BTUs/hr more than 500,000 BTUs/hr at temperatures of up to about 2,000 degrees Fahrenheit, well within the operating requirements of Stirling-cycle engine **134**.

Preferably, waste-oil-fired coil tube boiler **155** comprises at least one combustion chamber **147** containing coiled tube heat exchanger **202**, as shown. Preferably, water pumped through coiled tube heat exchanger **202** is heated by combustion flame **156**, as shown. The hot water exiting coiled tube heat exchanger **202** is preferably used to provide local domestic hot water or space heating within the waste oil electrical cogeneration system site. Preferably, combustion chamber **147** includes combustion gas discharge flue **170** to remove spent combustion gases from the system, as shown. It is noted that the configuration and operation of such a waste-oil-fired coil tube boiler is described in greater detail in, for example, U.S. Patent No. 6,085,701 to Stauffer et al., incorporated herein by reference for further examples of implementation engineering.

In the waste oil boiler taught by Stauffer et al. (U.S. Patent No. 6,085,701), combustion flame **156** is fired toward the back wall of combustion chamber **147**. Applicant prefers that, in applicant's waste-oil-fired coil tube boiler **155**, working fluid heat exchanger **136** is introduced into combustion chamber **147** through back wall **157** (as apposed to Smoker et al. and Stauffer et al., for example), thereby permitting a portion of the heat energy from combustion flame **156** to be transferred to Stirling-cycle engine **134**, as shown. Preferably, the configuration of working fluid heat exchanger **136** is such that combustion flame **156** is directed back in combustion chamber **147**, thereby maintaining the overall efficiency of the combustion and secondary heat transfer process, as shown (herein embodying wherein such combustion heat produced by such at least one combustion heater comprises at least one directed heat flow; at least one portion of such at least one primary heat exchanger is positioned to be in thermal communication with such at least one directed heat flow; and such at least one primary heat exchanger is structured and arranged to direct at least one portion of such at least one directed heat flow to such at least one secondary heat exchanger) . Upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, such as, to accommodate specific furnace thermal performance characteristics, user preference, advances in technology, etc., other positions of the working fluid heat exchanger within the combustion chamber, such as, for example, non-concentric, front mounted, etc., may suffice.

As one preferred example, Stirling-cycle engine **134** may comprise a 480 cc four-piston alpha configuration, such as Model STM 4-120 produced by Stirling Thermal

Motors, Inc. Using a waste oil burner having a combustion flame temperature of approximately 1,400 degrees Fahrenheit (as measured at working fluid heat exchanger 136), Stirling-cycle engine 134 produces about 40 hp at an average shaft speed of about 1800 rpm. Preferably, Stirling-cycle engine 134 is coupled to an induction- type electrical generator 138, preferably having a rated electrical output (after inverter processing) of 25kW at 480 VAC/3-phase at 60 Hz. Further, Stirling-cycle engine 134 preferably produces up to 150,000 BTUs/Hr of additional hot water from the engine's internal coolant circuit delivered through Stirling engine coolant lines 172, as shown.

It should be noted that, under appropriate circumstance, other Stirling-cycle engine/generator designs may be used within the above-described embodiments, for example, the Stirling engine/generator combinations produced by the Stirling Technology Company of Kennewick, WA, U.S.A.

FIG. 10 is a sectional view through typical waste oil combustor 130 according to the preferred embodiments of the present invention. It is noted that the configuration and operation of waste oil combustors (such as waste oil combustor 130) is described in greater detail in, for example, U.S. Patent No. 6,048,197 to Bieler, incorporated herein by reference for further examples of implementation engineering.

As generally discussed in Bieler, waste oil combustor 130 includes burner nozzle 321 and ignition assembly 117 to create a flame from the supplied waste oil 104, as shown. Preferably, waste oil combustor 130 also includes housing 323 in which is mounted fan 324 to supply large quantities of combustion air over nozzle 321 and ignition assembly 117 to support the creation of flame 156 in combustion chamber 147, as shown.

Preferably, burner nozzle assembly 370 includes burner nozzle 321 and ignition assembly 117 (embodying herein igniter means for igniting such environmentally hazardous waste oils after such environmentally hazardous waste oils have passed through such atomizing means, and further embodying herein at least one igniter structured and arranged to ignite such environmentally hazardous waste oils after such environmentally hazardous waste oils have passed through such at least one atomizer), as shown. Preferably, burner nozzle 321 includes nozzle housing 371 having passageways for the flow of compressed air 128 and waste oil 104 in a known manner to create a flame projected into combustion chamber 147.



Preferably, preheated waste oil **104** flows into burner nozzle **321** (embodying herein atomizer means for atomizing such environmentally hazardous waste oils prior to combustion, and embodying herein at least one atomizer structured and arranged to atomize such environmentally hazardous waste oils prior to combustion) to exit in a fine stream. Meanwhile, preheated compressed air **128** preferably flows through another passageway into burner nozzle **321** where the flow of compressed air **128** is directed in a slightly spiraled path. Preferably, compressed air **128** and waste oil **104** are combined at the tip of burner nozzle **321** to effect an atomizing of the waste oil stream, resulting in a combined stream of compressed air and atomized waste oil droplets being ejected from the tip, whereupon it is ignited into a flame by the electrodes **398**, of ignition assembly **117**.

It should be noted that the term “environmentally hazardous waste oils”, as used within this specification and the below claims, shall include within the definition, vegetable oils and similar oils used within the food industry. Furthermore, upon reading this specification, those with ordinary skill in the art will understand that, under appropriate circumstances, such as, for example, new industries, advances in processing technology, etc., the use of other oils, such as, synthetic oil, bio-engineered oils, etc., may suffice.

Although applicant has described applicant's preferred embodiments of this invention, it will be understood that the broadest scope of this invention includes such modifications as diverse shapes and sizes and materials. Such scope is limited only by the below claims as read in connection with the above specification. Further, many other advantages of applicant's invention will be apparent to those skilled in the art from the above descriptions and the below claims.